ORIGINAL ARTICLES

"METHOD OF SIMULTANEITY ANALYSIS" FOR CONSTRUCTING "MODEL FOR ESTIMATING IMPRESSION"

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Abstract: So far, the method of multiple regression analysis is mainly used for constructing the models to estimate impressions for exterior design for industrial or consumer products or looks of spaces. However, its results are not always highly reliable, because it is a parameter-dependent method and a small change of data to be analyzed may often make a big change of the result. For solving this problem, the author developed a new structure-dependent method for constructing more stable and reliable models. The resulting models relate impressions with certain specifications or impressions with certain impressions. In the new method, impressions for many objects by many respondents are measured, then relations between impressions are analyzed, under the hypothesis that "the existence of a structural relations among the 'simultaneous' responses from the 'same' respondent for the 'same' object is highly possible". A certainty of an average respondent with a certain impression [i] for the objects to have another impression [j] concurrently can be measurable through difference between conditional rate and general rate of another impression [j]. Then, a choice of a more probable combination constructs a model: "if impression [i] exists, then impression [j] also exists simultaneously". Besides, by regarding the specifications of the objects similarly to the measured impressions, relations between the specifications and the impressions can be established. Consequently, reference can be made between certain specifications and the impressions an average respondent can have.

Keywords: *Simultaneity analysis, Impression, Estimation, Structure-dependent method*

1. WHAT IS "MODEL FOR ESTIMATING IMPRESSION"?

We feel certain impressions for the objects such as exterior designs of industrial or consumers products or looks of spaces. Conversely, we can imagine certain objects such as exterior designs of industrial or consumers products or looks of spaces through some impressions provided. The "model for estimating impression" mathematically connects the objects with a corresponding impressions, by measuring impressions people might feel for the objects and by analyzing the result.

The construction of a "model for estimating impression" enables you to estimate explanations people are expected to give or impressions people will feel for an object of a specified design. You can also estimate other impressions people might concurrently feel in relation to a specified impression. Conversely, you can estimate specifications of a product design or a space people might imagine for a specified impression, or you can estimate explanations people might make as well (Figure 1).

Figure 1: Concept of "model for estimating impression"

2. PROBLEMS RELATED TO THE CONVENTIONAL METHODS FOR CONSTRUCTING "MODEL FOR ESTIMATING IMPRESSION"

Let's take the designs of products for example. The typical methods for constructing a "model for estimating impression" has been as follows. First, the specifications of each design of product such as shapes, colors, patterns, materials, parts and other attributes are extracted and straightened up. Second, the impressions of each object are measured through a method such as semantic differential method i.e. SD method. And through multiple regression analysis treating the result of the former as independent variables and the result of the

latter as subordinate variables, the correspondent variables of each are connected.

But models constructed through such a method have a problem of inability to conduct highly reliable estimation, since no logical or structural relationship between the independent variables and the subordinate variables are taken into account.

In order to solve this problem, the author developed the "method of simultaneity analysis" to find out structural relationships that should exist between the physical specifications of each object and the research outcome of its impressions. Such relationship found through this method also helps constructing a highly reliable "model for estimating impression".

3. FUNDAMENTAL PRINCIPLE OF "METHOD SIMULTANEITY ANALYSIS"

In the method of simultaneity analysis, a hypothesis is established for the outcome of a research into the impressions or explanations for the objects that says, "the existence of a structural relationship among the 'simultaneous' responses from the 'same' respondent for the 'same' object is highly possible". The structural relationship here means the cause-and-effect relation or the correlation. Based on this hypothesis, you will first find structural relationships "hidden" between a response i.e. impression or explanation, and another response. And through other expertise and experiences, you can select what is determined as appropriate as a "model for estimating impression". The "hidden" structural relationship among the measured data is that of the "simultaneity".

Let me explain the specific method and procedure through an example of analysis on a relationship between one impression and another impression. When the existence of an impression [i] ($i=1, \dots, I$) of an object [m] ($m=1, \dots, M$) by a respondent [n] ($n=1, \dots, N$) is expressed by $[a_{mni}]$ ($a_{mni}=0$ or 1), the proportion of the same respondent reporting impression [i] and impression [j] ($j=1, \dots, I$) to all the combinations of the respondents and the object for which impression [i] is reported: $[q_{ij}]$ ($0 \leq q_{ij} \leq 1$) is expressed by the formula (1).

$$(1) \quad q_{ij} = \frac{\sum_{\forall m} \sum_{\forall n} a_{mni} a_{mmj}}{\sum_{\forall m} \sum_{\forall n} a_{mni}} \left(\text{when } i \neq j, \sum_{\forall m} \sum_{\forall n} a_{mni} \neq 0 \right)$$

This value can be interpreted as the certainty or the possibility of impression [j] reported at the same time as the reporting of impression [i], however, this value includes the possibility of inadvertent reporting of impression [j] where no relation between impression [i] and impression [j] exists. This possibility can also be interpreted as the proportion of each object impression [j] is reported $[p_j]$ ($0 \leq p_j \leq 1$).

$$(2) \quad p_j = \frac{\sum_{\forall m} \sum_{\forall n} a_{mmj}}{MN}$$

As you subtract this value from $[q_{ij}]$ of the formula (1), the certainty of the impression [j] possibly reported concurrently with the impression [i], i.e., the certainty of "if [i] then [j]": $[r_{i \rightarrow j}]$ ($-1 \leq r_{i \rightarrow j} \leq +1$) can be expressed by the formula (3). Then, $[r_{i \rightarrow j} = +1]$ can be interpreted as "if [i] then [j]"; $[r_{i \rightarrow j} = -1]$ as "if [i] then not [j]"; and $[r_{i \rightarrow j} = 0]$ as "[i] and [j] are independent" respectively. By the way, "if [i] then [j]" takes the same format as the production rule which is one of the most typical knowledge expression.

$$(3) \quad r_{i \rightarrow j} = q_{ij} - p_j \quad (\text{when } i \neq j)$$

Here, as formulas (4) and (5) show, the respective proportion of each of the objects for which impression [i] is reported can be represented by $[p_i]$ ($0 \leq p_i \leq 1$) and the proportion of the objects for which impression both [i] and [j] are reported can be represented by $[p_{ij}]$ ($0 \leq p_{ij} \leq p_i, p_j$), to describe the formula (3) in the form of formula (6).

$$(4) \quad p_i = \frac{\sum_{\forall m} \sum_{\forall n} a_{mmi}}{MN}$$

$$(5) \quad p_{ij} = \frac{\sum_{\forall m} \sum_{\forall n} a_{mmi} a_{mmj}}{MN} \quad (\text{when } i \neq j)$$

$$(6) \quad r_{i \rightarrow j} = \frac{p_{ij}}{p_i} - p_j \quad (\text{when } i \neq j)$$

The first term of the right side of the formula (6), $[p_j / p_i]$ represents the proportion of impression [j] being reported under the condition which impression [i] is reported, and the second term $[p_j]$ represents the proportion of impression [j] reported under no such conditions. The certainty of "simultaneity" hidden

between on impression [i] and [j], or $[r_{i \rightarrow j}]$, can be obtained by subtracting the proportion (possibility) of [j], which is under no condition, from the proportion (possibility) of [j] under the condition of [i] being reported (Figure 2).

Figure 2: Explanation of simultaneity by Venn chart

Needless to say, $[r_{i \rightarrow j}]$ and $[r_{j \rightarrow i}]$ represent different meanings. $[r_{i \rightarrow j}]$ represents the certainty of "if [i] then [j]", that is to say, the extent of the certainty of estimation that you may feel impression [j] simultaneously when you feel impression [i]. And $[r_{j \rightarrow i}]$ represents the certainty of "if [j], then [i]" which is the extent of the certainty of estimation that you may feel impression [i] when you feel impression [j]. Even when "if [i] then [j]" may be sure, you should pay attention that "if [j] then [i]" may not necessarily be sure.

This principle can also be applied to the relationship of "if the impression both [i] and [j] are reported, then the impression [k] is reported at the same time". In this case, the certainty of "if [i] and [j], then [k] ($i \& j \rightarrow k$)", or $[r_{ij \rightarrow k}]$, is represented by the formula (7) (Figure 3).

Figure 3: Explanation of "double-folded" simultaneity by Venn chart

$$(7) \quad r_{ij \rightarrow k} = \frac{p_{ijk}}{p_{ij}} - p_k \quad (\text{when } i \neq j \neq k \neq i)$$

Also, when you apply this principle to the relationship of "under a certain condition A, the impression [i] is reported concurrently with the impression [j]", the certainty that "under the condition A, if [i] then [j] ($i(\in A) \rightarrow j(\in A)$)", or $[r_{i \rightarrow j} (i, j \in A)]$, can be represented by the formula (8) (Figure 4).

$$(8) \quad r_{i \rightarrow j} = \frac{p_{ij}}{p_i} - p_j \quad (\text{when } i, j \in A, i \neq j)$$

Figure 4: Explanation of "conditional" simultaneity by Venn chart

Figure 5: Confidence of certainty of simultaneity

By the way, the formulas (6), (7) and (8) are the most likely values of the certainties. And you can actually find more statistically probable simultaneity by calculating the statistically lower limit value (in fact, approximate value) of certainty of "if [i] then [j]", given the total number of objects being measured [L] ($=MN$) and the

standard normal score $[\gamma]$ defined for the certain risk level of the statistical estimation errors. Generally, more probable results can be obtained when samples are in larger volumes (Figure 5).

$$(9) \quad r_{i \rightarrow j}(\text{lower-limit}) = \frac{p_{ij}(\text{lower-limit})}{p_i(\text{upper-limit})} - p_j(\text{upper-limit})$$

$$= \frac{p_{ij} - \gamma \sqrt{\frac{p_{ij}(1-p_{ij})}{L}}}{p_i + \gamma \sqrt{\frac{p_i(1-p_i)}{L}}} - \left(p_j + \gamma \sqrt{\frac{p_j(1-p_j)}{L}} \right)$$

(when $i, j \in A, i \neq j$)

4. EXTENSION THE APPLICATION OF "METHOD OF SIMULTANEITY ANALYSIS"

4.1. Simultaneity between impressions and specifications

Explanation above has been for the analysis of the relationship between different impressions responded in the research and measurements. However, if you regard the specifications of the design of each object as data obtained through research and measurements just like reported impressions or explanations, you can also find "hidden" structural relationships between the specifications of the design of an object and the reported impression or explanation. And by reviewing the validity of this result, you can also treat this as a "model for estimating impression" that represents "high possibility or certainty of generating a certain impression for an object with certain specification" or conversely "high possibility or certainty of finding an object with certain specification for a certain impression being generated."

4.2. Extended interpretation of hypothesis

When you analyze the researched or measured data under a hypothesis that "the existence of a structural relationship among the 'simultaneous' responses from the 'same' respondent for the 'same' object is highly possible" using this analytical method, the size of the researched or measured data is likely to grow to give a satisfactorily reliable result. However, the impressions respondents have for the same object do not always differ person to person, and in many cases different respondents give similar responses. This means that the structural relationship in the mind of each of the respondents do not always differ from each other but resembles each

other in some cases.

This means you can omit the portion "from the 'same' respondent" from the basic hypothesis to expand the scope of hypothesis to "the existence of a structural relationship among the 'simultaneous' responses for the 'same' object is highly possible". Here, all the respondents is regarded as virtually a single person, and a "simultaneity" among the responses of different individuals is assumed. Or, if no difference is found between genders or ages or some characteristic groupings of the respondents, responses from multiple respondents of a group which is regarded as virtually having no difference as those from a single person in terms of assuming simultaneity.

Besides, while people's impressions can be generated for an entire object, they can also be generated for certain specifications of an object or their combinations. Therefore, "the same object" in the same hypothesis of this analytical method can be replaced with "the 'same' specification" to expand the scope of the hypothesis to "the existence of a structural relationship among the 'simultaneous' responses from the 'same' respondent for the object with 'same' specifications is highly possible". Take the designs of products for example. This corresponds to assuming "simultaneity" between products of a same type, a same shape, a same color, a same part, or a same material, and so on.

Through those ways of extension, researched or measured data can be analyzed from various perspectives to find a probable simultaneity, to be reviewed on the basis of other expertise and experiences to select an appropriate "model for estimating impression".

4.3. For other methods to measure impressions

So far, the author has explained the model on the premises that the measurement of impressions was done by explicitly asking the respondents whether they felt certain impressions for each of the objects. However, a small improvement is required in the case of the method of free keywords reporting (Figure 6) by which respondents are asked to freely respond with the explanations or impressions they explicitly recognized. In other words, in this type of measurement, reporting of the presence of an impression of an object can represent the impression the respondent felt for sure, however, when an impression is not reported, it is questionable whether the impression was not generated. That is, in

such researches and measurements using this method, you cannot find as much possible significance in non-reporting as the reporting of a fact since there can be cases that the non-reporting was an inadvertent outcome or due to the fact that the respondent already reported the impression using other similar impression words. Therefore, in such cases, we determine that formula (8) acknowledges the certainty of $i \rightarrow j$ ($r_{i \rightarrow j} > 0$) however it does not acknowledge the certainty of not being $i \rightarrow j$ ($r_{i \rightarrow j} < 0$) (Formula (10)).

$$(10) r_{i \rightarrow j} = \max \left(\frac{p_{ij}}{p_i} - p_j, 0 \right) \quad (\text{when } i, j \in A, i \neq j)$$

Or, when the semantic differential method is used for the measurement of impression, the measured outcome of impression [i] can be defined as $[a_{mni}]$ ($0 \leq a_{mni} \leq 1$) to be applied for the same formulas of (4), (2), (5) and (6), (7), (8), (9). However, it should be noted that the single polar scale where the responses take the form of the degree of an evaluation word should be adopted, and the bipolar scale where the responses take the form of the degree between the paired evaluation words should not be adopted. And it should be also noted that the measured outcome of impression [i], i.e. $[a_{mni}]$ should be regarded as analogue values between [0.0] and [1.0].

5. EXAMPLE OF THE CONSTRUCTION OF "MODELS FOR ESTIMATING IMPRESSIONS"

In order to construct "models for estimating impressions", the author conducted a research with use of the method of free keyword reporting for the object of "business bags for men". The stimuli were 200 colored photographs and the responders were 8 people varying ages and genders responded to each stimulus. In practice, one respondent responded to 5 stimuli. Since responses (in impression words and explanation words) were freely expressed, the interpretation of the connotation of the outcome was done using "electronic thesaurus" which

Figure 6: Example of sheet of free keywords reporting

Table 1: Calculated certainties of simultaneities on business bags for men

<i>if</i> refined, <i>then</i>	$r_{i \rightarrow j}$	<i>if</i> with no belt, <i>then</i>	$r_{i \rightarrow j}$	<i>if</i> urban, <i>then</i>	$r_{i \rightarrow j}$
1. with handle	0.51	1. stylish	0.45	1. stylish	0.32
2. green	0.34	2. not weary	0.21	2. businessman	0.23
3. thin	0.30	3. simple	0.20	3. famous brand	0.20
4. briefcase	0.27	4. look durable	0.17	4. simple	0.20
5. with belt	0.24	5. urban	0.17	5. high grade	0.20
6. gray	0.19	6. hard to use	0.17	6. expensive	0.19
impression $\rightarrow$ explanation		impression $\rightarrow$ explanation		impression $\rightarrow$ explanation	

<i>if</i> casual (a) and big enough (b),	$r_{ab \rightarrow j}$	$r_{a \rightarrow j}$	$r_{b \rightarrow j}$	<i>if</i> heavy (a) and expensive (b),	$r_{ab \rightarrow j}$	$r_{a \rightarrow j}$	$r_{b \rightarrow j}$
<i>then</i>				<i>then</i>			
1. for student	0.15	0.07	0.04	1. leather	0.15	0.07	0.04
2. for young	0.14	0.10	0.00	2. brown	0.14	0.10	0.00
3. convenient	0.11	0.05	0.01	3. with key	0.11	0.05	0.01
4. easy for use	0.10	0.06	0.00	4. with hook	0.10	0.06	0.00
5. practical	0.10	0.02	0.23	5. attache case	0.10	0.02	0.23
impression $\rightarrow$ explanation				impression $\rightarrow$ explanation			

Table 2: Comparison of simultaneities on different types of business bags for men

attache case	brief case	clutch bag	Dalles bag	shoulder bag
<u>look durable</u> →	<u>look durable</u> →	<u>look durable</u> →	<u>look durable</u> →	<u>look durable</u> →
1. look heavy	1. look heavy	1. look heavy	1. look heavy	1. look heavy
2. look hard	2. look hard	2. high grade	2. look hard	2. look hard
3. good design	3. last long	3. for men	3. last long	3. convenient
4. simple	4. orthodox	4. simple	4. big enough	4. easy to use
<u>businessman</u> →	<u>businessman</u> →	<u>businessman</u> →	<u>businessman</u> →	<u>businessman</u> →
1. look hard	1. look hard	1. look hard	1. look hard	1. look hard
2. for men	2. for men	2. for men	2. for men	2. look durable
3. high grade	3. high grade	3. look cheap	3. fashionable	3. business trip
4. for working	4. good design	4. not big	4. new sense	4. big enough
<u>old fashioned</u> →	<u>old fashioned</u> →	<u>old fashioned</u> →	<u>old fashioned</u> →	<u>old fashioned</u> →
1. fashionable	1. high grade	1. become dirty	1. look heavy	1. for aged
2. look durable	2. look hard	2. look hard	2. business trip	2. expensive
3. easy to carry	3. look durable	3. sober	3. for travel	3. look heavy
4. for commuting	4. for adults	4. simple	4. big enough	4. for men
<u>functional</u> →	<u>functional</u> →	<u>functional</u> →	<u>functional</u> →	<u>functional</u> →
1. big enough	1. simple	1. gay	1. last long	1. sober
2. for men	2. for men	2. for commuting	2. business trip	2. bad sense
3. business trip	3. easy to use	3. high grade	3. for student	3. look heavy
4. for working	4. good design	4. not weary	4. look soft	4. easy to use

the author separately developed. The impression words and explanation words of business bags, by the way, are classified into approximately 200 groups i.e. meanings. The electronic thesaurus absorbs "the difference in notation" and "the difference in expression" among various words to translate into the same "difference in meanings". The "difference in notation" here means words of similar pronunciation but of different notation thereby having more or less different usage and nuances, such as words written in Katakana characters, Hiragana characters, Kanji characters and Roman letters. And the "difference in expressions" here means such words as "fashionable", "in", "dressy", "vaguish" that are same in the meaning but different in the way of expressions.

Table 1 shows the analysis using this method on the reported explanation words found through the method of free keyword reporting for "business bags for men". This represents the "significant" relations of explanation words to impression words, impression words to explanation words and among impression words. On the other hand, Table 2 shows the result of simultaneity analysis carried out for each type of business bags and this finds both "significant" combinations irrelevant of the types and those relevant to the types of business bags. Such relations can be regarded as the alternatives for "models for estimating impressions" for estimating impressions from explanations, explanations from impressions or impressions from other impressions. However, in actual construction of models, the

differences among the results due to certain characteristics such as the genders or the ages of the respondents are also considered to pick up a valid relationship partially or generally applicable as "models for estimating impressions".

6. VALIDATION OF THE OUTCOME OF SIMULTANEITY ANALYSIS

Next, the author verified through a research whether the outcome obtained through this analytical method, i.e., the certainty of simultaneity was valid, or in other words, corresponding with human senses.

Specifically, the author extracted the combination of impression words with larger values of probable simultaneity ($\gg 0$) and smaller values (≈ 0) through this analytical method, and examined them through the following procedures. With regards to a simultaneity (combination) of "if impression [a] then impression [b]", the author asked respondents to "Imagine a business bag with an impression of [a]" and upon confirming they successfully imagined it, asked them to respond if the business bag in the imagination also gave the impression of [b] in "yes" or "no". 160 respondents responded for the relationship of 20 pairs including "simple" and "double-folded" combinations.

As a result, the simultaneity with larger certainty values such as "suitable for the mature → elegant" were affirmed, while the simultaneity with smaller certainty values such as "rainproof → suitable for the middle-aged" were

denied, generating significant difference as a whole. This result seems to affirm the analytical result using this method in general. However, in very rare cases, some combinations with certainty values were denied contrary to the analytical result, indicating the limit of direct application of this outcome as a reliable simultaneity, and showing the need of other expertise and experiences for the judgement of the outcome.

7. APPLICATION FOR THE "DESIGN SUPPORT SYSTEM" AND "DATA MINING"

7.1. Design support system

The "design support system" is a system that supports human activities in various phases of a process for users or designers to design the objects such as product design or the look of a space. The author built the "model for estimating impression" constructed through this analytical method to develop a new system that estimates an impression people might have for a specific design, or on the contrary, that selects the specifications of an object that corresponds to a specified impression to retrieve a matching image of the object.

Figure 7: Example of display screen of "salesclerk system"

The "salesclerk system" described in Figure 7 shows virtual shops that respectively sells bags, watches, shoes, telephones, word processors and chairs, where customers can converse with the virtual salesclerk of respective shops on the products in natural language. The customers can, for example, ask to salesclerk, "Do you have fashionable bags ?" or "Show me sober ones !" to retrieve objects through impressions (or desires) they

might have for the product. Or they can also ask questions concerning the specific or general expertise of the products such as "What is this part made of ?" or "Please explain what Dalles bag is ?"

"Image retrieval system by contents and impressions" in Figure 8 enables retrieval of images of various products or spaces such as office spaces, buildings, word processors, telephones, calculators, furnitures, stationeries, cars, clocks, eyeglasses and so on by specifying their contents or impression words. For the contents, a "PC" and a "personal computer" can be interpreted as meaning the same, and there is a built-in mechanism to break down a concept such as translating the "OA equipment" into its components such as "PCs", "word processors", "telephones", "copiers", "facsimiles" and so on. Besides, it can interpret impression words, no matter what notation they take, by their meanings, and in addition, it incorporates a mechanism to find impression words "close" to the specified impression words using "models for estimating impressions" and to enlarge the scope of search for retrieving the objects.

Figure 8: Example of display screen of "image retrieval system by contents and impression"

This system is actually used as a "supporting design environment" at the industrial design department of the company the author works for, in checking how the concepts contrived by the designers are materialized in other products or spaces to use this outcome as a hint to review the designs of products.

7.2. Data mining

The principle of this analytical method is general and can be used not only for the analysis of the mechanism of impressions but also for the objectives of finding

structural relationships "hidden" in the researched or measured data. Described as follows is a case of its application to "data mining".

Specifically, it is an application for extracting data using notes on "Dictionary for Computer Science and Technology"[1]. Here, the hypothesis of simultaneity is interpreted as "the existence of structural relationships among the terminology categorized in the captions under the 'same' items is highly possible". If you analyze the certainty of simultaneity among the words under this hypothesis, you can find such "synonymic" pairs as "OS vs operating system", "LAN vs local area network", "CPU vs processor", "AI vs artificial intelligence", "DB vs database" for simple simultaneities. Also, deeply related pairs such as "workstation vs PC", "UNIX vs standard", "MS-DOS vs standard", "hardware vs software", "UNIX vs OS", "network vs LAN" and "bank vs cash cards" are found.

Figure 9: Dictionary for Computer Science and Technology

In addition to the fact that the double-folded simultaneities gave many "synonyms" as a result, it also found more "persuasive" keyword combinations than the case of "single-fold": for instance, "PC & MS-DOS vs OS", "standard & OS vs UNIX", "standard & 16-bit PC vs Windows 3.1", "expertise & estimation vs AI" and "program & language vs programming language".

Moreover, by roughly grouping the keywords under categories such as "hardware", "software", "system", "telecommunication", "electronic devices" and so on, and limiting the scope of "simultaneity" analysis to the captions of the keywords contained in respective categories to conduct "conditioned" simultaneity analysis, more "persuasive" combinations in every one of

categories were found compared to "unconditioned" simultaneity search done for the entire captions.

8. CONCLUSION

The "method of simultaneity analysis" introduced in this paper is one of the methods to construct "models for estimating impressions" that connects the categorized specifications of objects with corresponding impressions. This method can produce highly reliable results, provided the specifications of the objects are satisfactorily categorized. However, it is very painstaking to categorize each of the specifications of objects.

Therefore, in order to reduce such backbreaking tasks, the author separately developed "new method of discriminant analysis by genetic algorithm" as a method to calculate many characteristic values of color images of objects and to connect them with corresponding impressions. Compared to the conventional analytical method and algorithm of discriminant analysis, this new method can find discriminant functions of higher discriminability suggesting its application for the estimation of impressions of color images of the objects whose specifications are yet to be categorized.

REFERENCE

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